9.—Amygdaloidal rock from Watheroo in the Permian Nangetty Formation, Western Australia

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Abstract

Amygdaloidal igneous rock has been recovered from the glacial Nangetty Formation at Tillite Creek in the Irwin River valley, Western Australia. The amygdales contain quartz, calcite, chlorite and epidote and are the same in other respects as amygdales in dolerite near Watheroo, 150 km south of Tillite Creek. The identity of these distinctive rocks confirms the essentially northward direction of Permian glacial transport suggested for the area, and may help to define the movement rather precisely.

Introduction

The Permian (Sakmarian) Nangetty Formation crops out in the valleys of the Irwin, Lockier, Greenough and Murchison Rivers in the northern part of the Perth Basin (Fig. 1). Its glacial origin was recognized by Campbell (1910) and confirmed by Woolnough and Somerville (1924), and details of the formation at Tillite Creek were given by Clarke, Prendergast, Teichert and Fairbridge (1951). The last-named authors described many rocks from the heterogeneous assemblage, and realized that some boulders of quartzite, breccia and chert have counterparts to the south in what has since been named Coomberdale Chert (McWhae *et al.*, 1958, p. 12). Most of the other material at Tillite Creek mentioned by Clarke *et al.*, *i.e.* "reddish or blackish hard fine-grained mudstone", gneiss, pegmatite, quartz-epidote rock, mica schist, quartz schist, porphyry, four varieties of granite and three varieties of epidiorite are believed to come from Archaean terrain east of the roughly north-south band of Moora Group rocks. Details of their provenance, however, have not been established.

Since the work of Clarke *et al.*, a glacial deposit at Bindoo Spring, 60 km northwest of Tillite Creek, has been examined by many geologists. This deposit contains fragments first identified by Playford and Willmott as Mt Scratch Siltstone, Enokurra Sandstone, Arrowsmith Sandstone, Beaconsfield Conglomerate and Arrino Siltstone, and their derivation from the Yandanooka area to the south-southeast is certain. There are also representatives of the Moora Group, and shield rocks east of the Darling Fault.

The above data provide the main evidence for the generally accepted view that the direction of Permian glacial transport in southwestern Western Australia had general westerly and northerly components (see for example Crowell & Frakes 1971, Fig. 10a). Apart from the work of Clarke *et al.*, few details of the evidence have been published, though most of it is in an unpublished report by Playford & Willmot.

This paper records the discovery of two new rock types at Tillite Creek, both of which have counterparts near Watheroo, 150 km to the south. One of the rocks, a red-brown siltstone with coarse dolomite grains resembles part of the Dalaroo Siltstone 2 km northwest of Watheroo. The other, with which this paper is concerned, is an amygdaloidal igneous rock of distinctive mineralogy and texture. Virtually identical rock has been recorded from bodies of rock that intrude and slightly metamorphose Dalaroo Siltstone within a strip of country 4 × 8 km immediately northwest of Watheroo by Teoh 1967 (see Fig. 1). The Tillite Creek rock (68275)* and a specimen of amygdaloidal rock from Watheroo (60145) are described below.

Petrography of the amygdaloidal rocks

The igneous rock from Tillite Creek is grey-green and fine- to medium-grained and contains irregularly shaped to roughly ovoid, black,

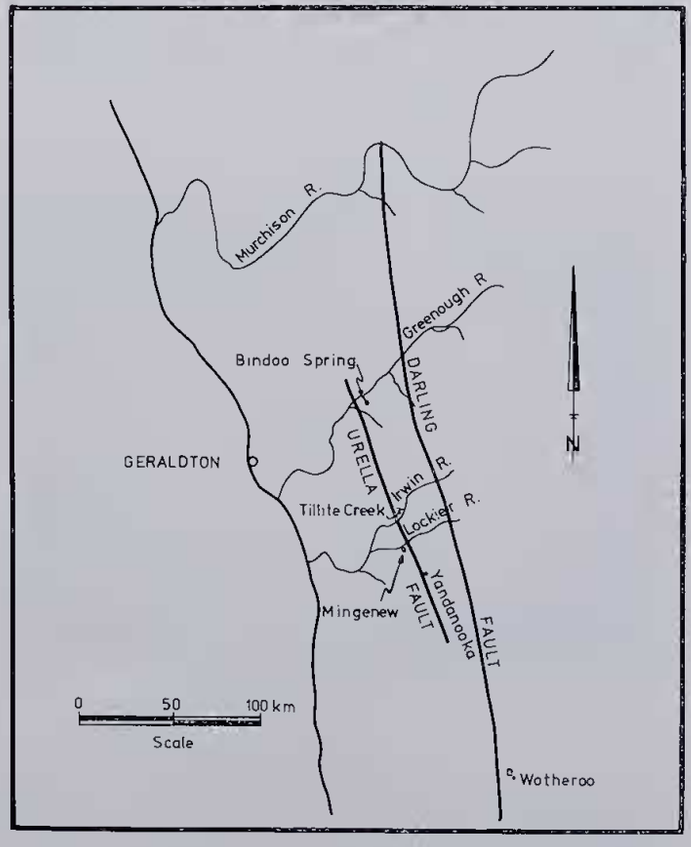

Figure 1.—Locality map showing Watheroo and Tillite Creek. The small rectangle north-west of Watheroo is the area within which amygdaloidal dolerite has been mapped by Teoh (1969).

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* All specimen numbers refer to the collection of the Geology Department, University of Western Australia.

and grey and black bodies up to a centimetre long that resemble amygdales. Under the microscope about 60% of the rock between the amygdales is made up of highly altered plagioclase laths with no apparent preferred orientation, and the rest is largely chlorite. There appears to be a palimpsest ophitic texture, but pyroxene is absent. There are numerous irregularly shaped masses of calcite in the rock; some plagioclase grains are completely converted to calcite, but most are only partly carbonated, and are charged with chlorite flakes. The unaltered plagioclase ranges from oligoclase to andesine. Epidote and sphene are scattered throughout the rock, and a few grains of hematite, pyrite and a black opaque iron mineral are present.

About 5% of the rock consists of the irregularly shaped to roughly ovoid bodies visible in hand specimen. In their most characteristic form they resemble amygdales and have a narrow discontinuous rim of calcite and quartz with a core of clear green, practically isotropic chlorite containing euhedra of epidote (see Fig. 2). Where the chlorite shows faint anisotropism, the anomalous interference tints suggest a micro-drusy structure of which there is little indication without the analyser. There is a tendency for grains of sphene in the rock to be concentrated near the margins of these apparent amygdales. In some places the quartz of the rim is lath-like, and seems to have replaced plagioclase.

Eight of the epidote crystals in the bodies described above were measured with the universal stage. Forms identified are {001}, {100}, {110}, {101} and {111}. Six-sided crystals showing the front and basal pinacoids and a dome

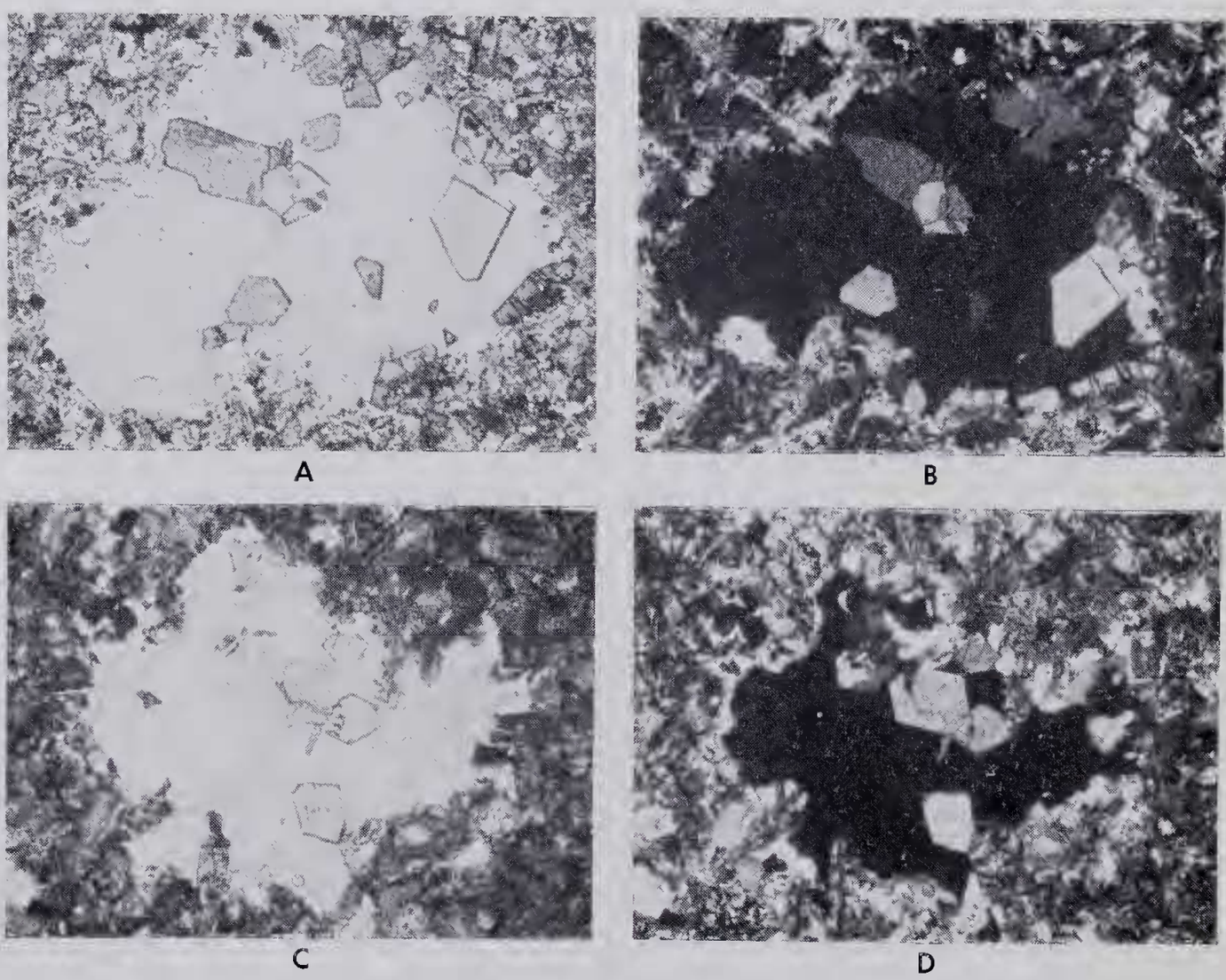

Figure 2A.—Specimen 68275 (altered dolerite) from Tillite Creek. Note the amygdale filled mainly with chlorite (light grey), euhedra of epidote (grey with dark borders), and the discontinuous rim of quartz (white). Small dark grains outside the amygdale are sphene. Plane-polarized light, x 25. Univ. West. Aust. Geol. Dept. negative No. P2612. B.—Specimen 68275, same amygdale illustrated in Figure 2A. The chlorite is black, and some epidote shows twinning. Crossed polarizers, x 25. Univ. West. Aust. Geol. Dept. negative No. P2613. C.—Specimen 60145 (altered dolerite) from Watheroo. Note the amygdale filled mainly with chlorite (light grey), the euhedra of epidote (grey with dark borders), and the discontinuous rim of quartz (white). The small dark grain in the amygdale (left centre) is sphene; most of the sphene is just outside the amygdale. The resemblance to specimen 68275 from Tillite Creek is clear. Plane-polarized light, x 36. Univ. West. Aust. Geol. Dept. negative No. P2610. D.—Specimen 60145, same amygdale illustrated in Figure 2C. Crossed polarizers, x 36. Univ. West. Aust. Geol. Dept. negative No. P2611.

are common in thin section, and some show twinning on 100. The pleochroic scheme is X = colourless, Y = pale yellow, Z = olive-green with absorption X < Y < Z. Dispersion is pronounced with r > and r < v in different crystals, suggesting crossed dispersion. X∧c (7 grains) measures 2°, 4°, 5°, 5°, 5½°, 6°, 7°, and (—)2V (4 grains) measures 68.5°, 69°, 70°, 75°, with measurements reproducable to within 2°. These properties are the same as those for epidote in the pistacite range (Winchell & Winchell 1956, Fig. 343).

There are other bodies in the rock in which the minerals are arranged differently. In a few the calcite rim is thick and continuous, and chlorite is restricted to a small core. Some of the bodies have a discontinuous rim of quartz, an irregularly shaped inner layer of slightly fibrous chlorite containing epidote euhedra, and a core of granular calcite and very fine grained quartz. Other, commonly complex bodies, have cores either of calcite or microcrystalline quartz. Some very irregularly shaped masses, generally made up essentially of chlorite, epidote and calcite, have only vaguely defined boundaries with the surrounding chlorite-rich and calcite-rich groundmass, and have the appearance of having replaced the rock rather than having filled cavities in it. Nevertheless, for simplicity all these bodies are from now on called amygdales, and they have one consistent feature: the epidote either penetrates the chlorite or is enclosed by it.

The amygdaloidal rocks at Watheroo resemble the Tillite Creek specimen described above. Specimen 60145 was collected from a dyke-like body that roughly parallels and locally crosses the Geraldton Highway between about 5 kilometres and 10 kilometres north of Watheroo. Outcrop of rock similar to that of specimen 60145 is found 0.15 kilometres north of the Longreach turnoff, 9 kilometres by road north of Watheroo.

Specimen 60145 is grey-green, fine-to medium-grained, and contains irregularly shaped to roughly avoid, black, and light grey and black bodies up to a centimetre in diameter. In thin section there seems to be a relict ophitic texture, but in places where most of the original minerals have been changed, there is little evidence of such texture. Laths of plagioclase have commonly been replaced by chlorite, epidote and calcite, and locally by quartz. Interstitial material consists partly of pale brown and pale green fibrous amphibole, very rarely with a core of augite. There are also irregularly shaped patches of chlorite and calcite, and epidote in the form of clear crystals and cloudy fine-grained aggregates is common. Other constituents include small grains of sphene, an opaque mineral (probably leucoxene) and fine aggregates of interstitial quartz. The rock is probably an amygdaloidal quartz dolerite that has been extensively auto-metamorphosed.

Some amygdales resemble those in the Tillite Creek boulder very closely (Fig. 2). In general, they have the same mineralogy and show the same range in mineral arrangement and their contained epidote euhedra exhibit the same morphology and pleochroism. There is a similar tendency for small grains of sphene to be concentrated in the rock near the amygdales. Measurements with the universal stage on epidote in specimen 60145 are as follows: X∧c = 3½°, 5° (2 grains) (—)2V = 70°, 71° (2 grains). Dispersion is pronounced with r>v and r < v in different crystals, suggesting crossed dispersion. The epidote is thus indistinguishable optically from epidote described in the Tillite Creek rock.

Other similar Watheroo rocks contain amygdales with a higher proportion of epidote, and grade into rocks in which the epidote resembles glomeroporphyritic aggregates.

Discussion

Epidotized amygdaloidal rocks have been recorded from the Proterozoic Fish Hole Dolerite in the Kimberley Region by Dow & Gemuts (1969, pp. 28, 30-31), but apart from the Watheroo rocks, intrusive amygdaloidal bodies have not been reported elsewhere in Western Australia. The striking similarity of the material from Tillite Creek and Watheroo makes their common origin very likely.

The amygdaloidal dolerite at Watheroo was mapped as dykes cutting the Dalaroo Siltstone both by Teoh (1967), who discussed its petrology, and by Low (1969), who did not distinguish it from the other, non-amygdaloidal dolerite in the area. The strike of the amygdaloidal dolerite parallels that of the Moora Group fairly closely, and it may be at least locally concordant. Detailed mapping is necessary to check its structural relationships to the Dalaroo Siltstone and to determine its extent. It has not been recognized far north of Teoh's area, and is known to be absent from the Moora area. If it proves to be restricted to the vicinity of Watheroo, it will demonstrate rather precisely the direction of travel of Permian ice eroding the Watheroo area, and will indicate the distances of transportation involved.

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